DOCUMENT RESUME

ED 460 143 TM 033 617

AUTHOR Wilson, Jeni
TITLE Methodological Difficulties of Assessing Metacognition: A New Approach.
PUB DATE 2001-12-00
NOTE 15p.; Paper presented at the Annual Meeting of the Australian Association for Research in Education (Fremantle, Western Australia, Australia, December 2-6, 2001).
AVAILABLE FROM For full text: http://www.aare.edu.au/index.htm.
PUB TYPE Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Audiotape Recordings; *Elementary School Students; *Evaluation Methods; Foreign Countries; Intermediate Grades; *Interviews; Mathematics; *Metacognition; Problem Solving; *Research Methodology; Videotape Recordings
IDENTIFIERS Australia

ABSTRACT

This paper discusses methodological difficulties in studying metacognition and proposes a new multi-method technique for assessing student metacognitive behavior. The major aim of the study was to develop and apply a strategy for assessing metacognition within the context of mathematical problem solving. Data were collected from 30 year-6 students in Australia. Students were involved in three clinical interviews each in which they followed the same procedure with different types of mathematical tasks. The multi-method approach included observation, the clinical interview, and video and audio recordings. The interviews incorporated self-reporting and, in some cases, the think-aloud technique. Specially designed metacognitive and cognitive action cards were used to stimulate student responses about their thinking. Findings raise doubts about using students' "out of context" verbal reports as data without corroborating evidence. The findings also call into question the validity of questionnaires or interviews when used in isolation. Results also demonstrate the difficulty students have in identifying their general use of metacognitive behavior. The multi-method approach used in this study responded to issues of concern about verbal data and provided students with opportunities to identify, check, and discuss their thinking. (Contains 37 references.) (SLD)

Reproductions supplied by EDRS are the best that can be made
from the original document.

ED 460 143

Paper presented at the Australian Association for Research in Education Conference, Fremantle, 2001

Methodological Difficulties of Assessing Metacognition: A New Approach

Dr. Jeni Wilson

Abstract

Metacognition has been identified as having an important role in many aspects of education, yet specific details about how students use metacognition when they tackle problems is not well researched. Research in the field has spanned three decades, therefore this field would not be considered a new frontier but the assessment of metacognition is.

One of the difficulties associated with researching metacognition is that the term lacks clarity. The research implication is that parametres need to be defined to conduct assessment research. Another problem for researchers interested in metacognition is that techniques used in the research of metacognition, such as, verbal self-reporting are often criticised.

This paper will discuss important methodological difficulties of researching metacognition and propose a viable, new multi-method technique used for assessing student metacognitive behavior. This new multi-method interview technique was used with Year 6 students from three different Victorian schools undertaking a range of non-routine mathematical problems but the results may well be applicable across other age groups and across different curriculum domains.

Introduction

Verbal reports can provide researchers with ambiguous and contradictory data about students' actual practices, but researchers in the field of cognitive study need self-reports as a source of data. The following student quotes from this research highlights the difficulties for researchers when trying to interpret meaning from student reports.

> *"Well I always do that but most of the time I don't."* (Louisa)
> *"I never, hardly ever do it in the classroom."* (Therese)
> *"When I finish a problem I do check it, but when I don't ... "* (Peter)

TM033617

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY

J. Wilson

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

✓ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

BEST COPY AVAILABLE

These student statements were made by during the process. As they stand, they provide ambiguous and doubtful data about students' actual practices and their thinking. There are a number of possible explanations for such data, for example students may be unsure about what they do, unable to express what they do and think, they may be inventing answers or trying to please the researcher. When Julie was asked to explain discrepencies in verbal data she responded: "Maybe I was off with the fairies or pixies or something?" (Julie)

This article reports on verbal reports made by Year six students and the credibility of these in the context of a multi-method approach to researching metacognitive thinking. This paper raises important questions about students' verbal reports in the area of metacognition and discusses how the limitations of self-reports can be reduced.

Aims and Terms

The major aim of this study was to develop and apply a strategy for assessing metacognition within the context of mathematical problem solving. As well as investigating the effectiveness of particular assessment strategies, the study enabled an examination of the nature of metacognition and the relationship between metacognition and task type. The focus of this paper is on methodological difficulties of assessing metacognition.

One of the initial challenges for researchers in this field is defining the term metacognition. Metacognition was used in this research to refer to the *awareness individuals have of their own thinking and their ability to evaluate and regulate their own thinking*. The three functions of metacognition were identified as: Metacognitive *Awareness*, Metacognitive *Evaluation* and Metacognitive *Regulation*.

Contextualising the Research

The data collection involved thirty Year Six students in three different schools. Ninety interviews were conducted, with each student being interviewed three times. Students were involved in three clinical interviews (plus a familiarisation task) in which they followed the same procedure with different types of mathematical tasks. The multi-method approach included: observation; a problem-based clinical interview (incorporating self-reporting and in some cases the think aloud technique); video and audio recordings

The most unique and revealing component of the clinical interview was the use especially designed metacognitive and cognitive action cards (see Appendix 1) to stimulate student responses about their thinking. This procedure is discussed in length later in this paper.

While the centrality of metacognition in the problem solving process is widely recognised (Stacey 1990; Munro 1993), details of metacognitive behavior involved during problem solving are few (Goos, 1998). This is largely due to methodological problems (Garofalo and Lester 1985; Nisbett and Wilson 1977; Nuthall and Alton-Lee 1995). The multi-method interview was designed to document the nature of metacognition during mathematics problem solving and this paper reports on a compelling methodological findings.

In the process of developing a new multi-method approach which could confidently be used with young students for studying metacognition, a number of checking procedures were included in the interview protocol (discussed later). One such procedure allowed the comparison of students' comments made about metacognitive use within the context of particular problems, and student comments about their reported use of metacognition at other times. The results were surprising. These are discussed after a brief review of the literature on methodology and an overview of the Multi-method technique developed for this study.

Verbal Self-Reporting Issues

The use of verbal methods in the collection of data on cognitive and metacognitive processes is controversial (Ericsson and Simon 1980; Nisbett and Wilson, 1977; Nuthall and Alton-Lee, 1995). There are several questions related to the value of self-reporting and criticisms about the possible impact of self-reporting on cognitive processes. One of the major criticisms of verbal reports as a data collection devise is that specific thoughts, triggered by the interview process itself, may be reactive and may alter the cognitive thoughts being studied (Cavanaugh and Perlmutter 1982).

Meichenbaum, Burland, Gruson and Cameron, (1985) claimed that the most recurrent and serious concerns relate to the accessibility, veridicality and completeness of verbal reports. Such verbal report problems are even more an issue when dealing with children with limited linguistic capabilities. Cavanaugh and Perlmutter (1982) and Wellman (1985) are most critical of the verbal interview, claiming that it has the most 'methodological liabilities and poorest track record' (1985 : 198) for assessing cognition, especially with children.

Nisbett and Wilson (1977) seminal paper argued that asking students to generate a verbal report on a general procedure or strategy may not accurately describe their actual cognitive processes. But Ericsson and

Simon (1980) analysed Nisbett and Wilson's (1977) work and found it to have limitations. Ericsson and Simon (1980) criticised the earlier work on several grounds including: an undefined framework and ignoring experimental conditions which may impact upon the results. They concluded that verbal reports can provide a valuable and reliable source of information about cognitive processes.

Cognitive research focuses on behaviors which are not directly observable, therefore, indirect forms of measurement must be developed (Weinstein and Meyer, 1991). Variations of self-reporting have been developed in response to these concerns. Self-reporting is often associated with studies of metacognition. When a student is asked to self-report they may be given a hypothetical or real problem to discuss. They are asked to either concurrently, retrospectively or hypothetically explain the strategies they might apply or have applied to the problem. The reports are interpreted by the researcher as evidence of metacognition. This technique has sometimes involved thinking aloud. The think aloud technique requires students to verbally express their thoughts as they perform a task.

Brown (1987) and Meichenbaum et al (1985) expressed wariness about the veridicality of self-reports. Brown alluded to the possible effects of self-reporting on the thinking processes: 'Asking subjects to report on internal events that are not readily available to such inspection may significantly impair the processes on which they must report.' (Brown, 1987 : 76).

The timing of self-reporting has been raised by some researchers as an issue. This can be particularly problematic in studies of metacognition. The question of the accuracy of student post performance self-reports poses a dilemma for researchers is deciding whether reported metacognition represents what has occurred or what students think may have occurred (Meichenbaum, et al. 1985). Concurrent verbalisation technique with no interviewer intervention is least prone to study environment effects and to 'incompleteness and inconsistency of some verbal data' according to Scott (1994: 537) and that this is the most suitable for collecting problem solving data.

The most difficult problem when researching cognition, is when the mental process under question is one the subject does not normally pay attention to. Feil and Gatti (1993) stated that: 'Under these circumstances, obtaining a clear response or one that truly reflects the subject's actual internal processing may be difficult' (1993 : 630) but they suggested that one

method for overcoming these problems is to use specific 'thinking aloud' probes.

Students may not be able to recall their metacognitive acts because they some of them may have become automatised (Ericsson and Simon, 1980; Mc Koon and Ratcliff 1992). If students do not report cognitions it is difficult to determine whether the absence is actual or just not reported. Schoenfeld (1985) questioned whether verbal reports are accurate reflections of the processes used. Even with appropriate methodological care, he suggested that caution needs to be taken when interpreting verbal data. Schoenfeld (1985) argued that any methodology, can illuminate some aspects of behavior but distort others. He suggested that environmental factors, such as the perceived need of subjects to perform, their beliefs about the research requirements or their beliefs about the discipline can affect the results. Schoenfeld (1985) contended that verbal data should be compared and contrasted with data from other sources. This contention is well supported by others and basic to the technique developed in this study.

To maximise the completeness of verbal reports, enquiry immediately after the event is preferable, the task should be short and probing should be minimised. Ericsson and Simon (1980) recommended that internal consistency of results must be examined. Further they claimed that in trying to say what one was thinking, the subject might not remember, might misremember, or invent memories (for example, describing strategies that have just occurred to them). Genest and Turk (1981) agreed that reports are likely to be incomplete. While Ginsburg, Kossan Schwartz and Swanson (1983) also argued that self-reports can never be complete, they add that no data source can ever be complete or provide all answers needed.

The literature identifies a number of problems associated with verbal reports but any study which examines thinking processes must involve subjects reporting on their own thinking, therefore ways to minimise the limitations of verbal self-reporting must be investigated.

Reducing the Limitations of Verbal Self-Reporting

There are a range of suggestions made about ways to reduce the limitations of verbal reports. Some have been reviewed in the preceding section. Those discussed in this section are particularly pertinent to this research that is concerned about thinking processes and problem solving. Ericsson and Simon (1980) claimed that there are several issues that must be

attended to when considering verbal reports as data. These include: the effects on the cognitive processes, the completeness of reports and the consistency of reports. Further they suggested that generalisability and validity and the design of objective methods for encoding and analysing protocols are a concern. Ericsson and Simon (1980) argued that verbal reports should be collected with other records of behavior, consistency of results can then be checked.

In order to obtain reliable verbal data, retrospective self-reports should be obtained as soon as possible after the event (Feil and Gatti 1993 and Meichenbaum, et al 1985) . Otherwise the accuracy of verbal reports deteriorates as the time between the 'event' and the interview increases. 'Stimulated recall' (Miles and Huberman 1984) has often been used to gain access to the perceptions of the participants after the activity and without interrupting 'thought in action'. Usnick and Brown (1992) promoted the use of 'stimulated recall' as an effective tool to probe students problem solving thinking. By replaying recorded (audio or video) material and presenting work samples to students, retrieval cues (Adair and Spinner, 1979 and Meichenbaum et al, 1985) are provided to the student so that s/he can more easily explain what s/he was thinking at the time.

Such cues have been promoted by Randhawa (1994), to capture the cognition of the problem solver. She discussed the difficulties associated with assessing internal actions: 'Problem solving in any domain requires, among other things, encoding and translation, which are internal and unobservable. To understand the process of problem solving these internal mechanisms must be externalised.' (1994 : 218). Thus Randhawa suggested videorecording of think-aloud protocols along with clinical interviews is non-intrusive.

Adair and Spinner (1979) also provided guidelines about enhancing the accessibility and veridicality of self-reports. They suggested that the researcher discusses the importance of honesty with subjects. The selection of tasks which legitimise disclosure of cognitions was also considered crucial by Adair and Spinner (1979).

There seems to be no single verbal assessment method which cannot be criticised on some grounds. But Hacker, Dunlosky and Graesser, (1998) posited that if metacognition is defined as conscious and deliberate thoughts about one's own thinking, then these thoughts are potentially controllable, reportable and therefore accessible to the researcher. It is

argued that a technique would be considered more reliable if it combined methods. The multi-method approach was designed to capitalise on the strengths of particular techniques and avoid the disadvantages of each individual method.

Development of the Multi-Method Interview

This study employed a new technique that drew on and combined the strengths of the many commonly used strategies. The multi-method interview was designed as a result of unsatisfactory pilot study findings. The technique also responded to published criticisms of previous metacognitive research (Clarke, Stephens and Waywood, 1992; Clarke, 1996; Garofalo and Lester, 1985; Ginsburg et al, 1983), particularly those about verbal methods (Nisbett and Wilson, 1977 and Nuthall and Alton-Lee, 1995) and to the recommendation for new research methods to assess metacognition (Cavanaugh and Perlmutter 1982; Dunlosky 1998; Garofalo and Lester, 1985; Meichenbaum et al, 1985; Mulcahy, Short and Andrews, 1991; Randhawa, 1994).

The new approach included: observation; a problem-based clinical interview (incorporating self-reporting, sometimes 'think aloud' and a card sorting task); video and audio recordings. The card sorting task drew upon items from an earlier pilot questionnaire (related to metacognitive and cognitive actions), a Likert type procedure was implemented in a more 'active hands on' way. A total of fourteen metacognitive action statements (called action cards), each associated with one of the three metacognitive functions (Awareness, Evaluation and Regulation), were listed individually on playing cards (see Appendix 1). Multiple statements were used to improve the validity of the measurement technique (Fowler 1984; Reid 1990). Cards listing cognitive behaviors and blank cards were also provided.

During the clinical interviews students were asked to attempt a given mathematics problem. Students were familiar with the language on the cards and the card sorting routine. Their attempts were video recorded. After attempting the given task students were asked to sort the cards into two piles: cards that represented their thinking during their problem solving and those that were not applicable. Students were then asked to place the cards in sequence according to how they solved the problem.

Cards were provided to give students a means to express their thinking. The use of the action cards eliminated the "Don't know' responses which were given at the trialling stage when only questionnaires and structured interviews were used to assess student metacognition. Haynes (1997) supported the objective of providing cues for discussing thinking: 'How

can one be metacognitively aware or reflective without a language which to think about oneself?' (1997: 6).

Checking Procedures

To ensure that the students' card sequence was an accurate representation of their thinking, after the students had placed the cards in order, the video of their problem solving attempt was replayed. While watching the video, students were asked to point to the particular card that represented their thinking and behavior at each moment of the problem solving process. The video was stopped as many times as the students wanted. If they wished to, students could change the cards by discarding, adding or changing the sequence.

Students took the task of card sorting and checking very seriously, they took their time and often changed their selection when they rechecked the discard pile. The most frequent response was to add cards.. Students also sometimes changed the order and selection (more rarely) after watching the video. On most occasions, students changed their card sequence slightly (up to 4 changes). They usually added some cards by writing on the blank cards. Sometimes students eliminated some cards when checking their sequence against the video. There were some occasions when card sequences were not changed but every student changed their sequence at least once during the three interviews.

At the end of session two, after completing three tasks (including the familiarisation task) students were given the metacognitive action statements only and asked to indicate if and how often they generally did these things when they solved mathematics problems. Students sorted these cards into self-chosen categories such as: always, usually, sometimes do and never. This task was used to check what students said they do when they solve mathematics problems against their reported actions during the interviews. In most cases this demonstrated that student reports of what they did during the multi-method interviews was not the same as what they said they generally do when they solve mathematics problems. Sometimes students said they never did a particular action, but they had reported this action in one or both of the multi-method interview/s, or they said they always did a particular action but they had not reported doing it during either of the multi-method interviews.

When discrepancies occurred students were asked during the following week (session three) to explain why they thought there may be a difference. It is

noted that there was the only student who had used every metacognitive action statement during both interviews as she had claimed she generally did. This checking procedure raised questions about the difference between the student reports.

Verbal Reporting as Data: In Context and in General

The issue of contextual and temporal variation in metacognitive activity is highlighted by students' comments recorded during the second multi-method interview. Metacognition is dynamic, it responds to contextual and task features. Metacognition is activated according to challenge (such as in the non-routine tasks used in the study), when difficulties are encountered or when routines are not working. If everyday classroom tasks differ from the research tasks it would be expected that students would find it difficult to compare the way that they generally solve problems and how they relate their actions to those used during the multi-method interviews.

A number of other reasons could be forwarded to help explain the question of the difference between the students' reports within context (of the multi-method interview) and generally (applying to mathematics problem solving in general):

- Student reports of their own general behavior patterns are not accurate.
- Many or most students are not aware of what they are doing.
- Cards may be misinterpreted or interpreted in different ways on different occasions by individual students.
- It is difficult for students to generalise out of context.
- Different types of tasks require different types of responses, for example, students would not need to change the way they were working if their strategies were being successful.
- The level of difficulty determines the need for particular cards and therefore the reported sequence, for example, if the task was not recognised as similar to one they have done they may need to make a plan to work it out.
- The multi-method interviews create a context seen by students as different to problem solving at other times.

Although the first three possible reasons seem feasible these are not supported by the data. Student confidence in card selection and consistency in sequences across individuals, grades and schools suggests students can report their metacognitive thinking with the use of the action cards.

An important methodological problem for many researchers is whether their questions or tasks (interview, questionnaire or in this case action cards) assess

what the researcher wants to know (Cavanaugh and Perlmutter 1982). In order to check internal validity, one third of the students were asked to explain what they would be thinking if they selected particular action cards. Their responses confirmed that their interpretations were consistent with the intensions of the researcher for each card and demonstrated high internal validity for each card. Therefore misunderstandings of the cards was dismissed as a possible reason for discrepancies in reports. Student explanations for the differences in their reports mostly related to task variation, task difficulty and memory.

As well as providing data on verbal reports, other conversations during the multi-method interviews yielded interesting data about the nature of metacognition and classroom activities but as these are not central to the topic of this paper they are not discussed here (see Wilson, 2000)

Discussion and Conclusion

This paper has addressed important methodological questions about using student's verbal reports of their own thinking as data. Of central interest to this report is the confidence which can be attached to what student's report about their metacognitive thinking. The results raise doubts and questions about using students 'out of context' verbal reports without as data without corroborating evidence.

The results call into question the validity of questionnaires or interviews when used in isolation. The accuracy of either verbal data collection method, when used alone, as a suitable tool to measure a child's metacognitive repertoire must be questioned. Students statements (such as those included in this article) could not be easily interpreted without further clarification and in the light of other data. When verbal data is compared and contrasted against data from other sources, consistency of results can then be checked (Ericsson and Simon, 1980). Cohen and Manion (1994) , Schoenfeld (1985) and Wellman (1985) suggested the idea that one way to validate data is to compare it with another measure that is valid. If the two measures agree validity is assumed.

Although Savage claimed that: 'Asking a child how he went about solving a problem is the next best thing to getting inside his or her head.' (Savage 1994), a notion supported by Ginsburg (1983) and Pines, Novak, Posner and Van Kirks, (1978), individual verbal reporting techniques do not provide hard evidence which may be documented with the additional use of cards and videorecordings that can be checked, rechecked, verified and justified.

The results of this study also indicate the difficulty students have with identifying their general use of metacognitive behavior. It is asserted that

verbal responses about metacognition must be considered in a practical context and examined immediately after the event.

Any study involving children and the examination of their thinking processes must be involve self-reporting. While the limitations of self-reporting procedures are acknowledged, it is noted that none of the alternative assessments have proven to be unproblematic. Because of the influence of cognition and metacognition on behavior and learning, self-reporting methods must be developed and refined (Genest and Turk 1981) .

It is suggested that the multi-method interview satisfactorily responded to issues of concern about verbal data as presented throughout this article. Consistency within student responses during the multi-method interviews is taken as indicative of the reliability of the multi-method interview for accessing student's metacognition during mathematical problem solving. This study has focussed on the assessment of metacognition within mathematics, but it could be adapted to other curriculum domains and for other age groups.

The multi-method interview provides opportunities for students to identify, check and discuss their thinking. Instead of self-reports being considered being: "Off with the fairies or pixies or something." (Julie), verbal reports should then be interpreted, presented and viewed with more confidence.

References

Adair, J. and B. Spinner (1979). Subjects' Access to Cognitive Processes. University of Manitoba, Unpublished Manuscript.

Brown, A. (1987). Metacognitive, Executive Control, Self Regulation and Mysterious Mechanisms. Metacognition, Motivation and Understanding. F. Weinert and R. Klume. New Jersey, Erlbaum Hillsdale: 65-117.

Cavanaugh, J. and M. Perlmutter (1982). "Metamemory: A critical examination." Child Development 53: 11-28.

Clarke, D. (1996). Assessment. International Handbook of Mathematics Education. A. Bishop, K. Clements, C. Keitel, J. Kilpatrick and C. Loborde. Dordrecht, Kluwer: 327-370.

Clarke, D., M. Stephens, A., Waywood (1989). Communication and the Learning of Mathematics. Paper presented at AERA Conference. San Francisco: 1-32.

Clarke, D., M. Stephens, A., Waywood (1992). Communication and the Learning of Mathematics. Mathematics Assessment and Evaluation: Imperatives for mathematics educators. T. Rombery. New York, State University of New York: 184-212.

Cohen, L. and L. Manion (1994). Research Methods in Education. Fourth Edition. London, Routledge.

Dunlosky, J. (1998). Epilogue: Linking metacognitive theory to education. Metacognition in Educational Theory and Practice. D. Hacker, J. Dunlosky and A. Graesser. Mahwah, New Jersey, Lawrence Erlbaum: 367-381.

Ericsson, K. and H. Simon (1980). "Verbal Reports as Data." Psychological Review 87(3): 215-251.

Feil, P. and J. Gatti (1993). "Validation of a Motor Skills Performance Theory with Applications for Dental Education." Journal of Dental education 57(8): 628-633.

Fowler, F. (1984). Survey Research Methods: Applied social research methods. Beverly Hills, Sage.

Garofalo, J. and F. Lester (1985). "Metacognition, Cognitive Monitoring and Mathematical Performance." Journal for Research in Mathematics Education 16: 163-176.

Genest, M. and D. Turk (1981). Think-Aloud Approaches to Cognitive Assessment. Cognitive Assessment. T. Merluzzi, L. Glass and M. Genest. New York, The Guilford Press: 233-269.

Ginsburg, H., N. Kossan., R. Schwartz., D. Swanson (1983). Protocol Methods in Research on Mathematical Thinking. The Development of Mathematical Thinking. H. Ginsburg. New York, Academic Press: 7-47.

Goos, M. (1998). "I don't know if I'm doing it right or I'm doing it wrong!" Unresolved uncertainty in collaborative learning of mathematics. MERGA 21, Queensland.

Hacker, D., J. Dunlosky, A., Graesser (1998). Metacognition in Educational Theory and Practice. Mahwah, New Jersey, Lawrence Erlbaum.

Haynes, F. (1997). "Teaching to Think." The Australian Journal of Teacher Education 22(1): 1-12.

Karoly, P. (1981). Self-Management Problems in Children. Behavioral Assessment of Childhood Disorders. E. Mash and L. Terdal. New York, Guilford.

Mc Koon, G. and R. Ratcliff (1992). "Inference During Reading." Psychological Review 99: 440-466.

Meichenbaum, D., B. Burland., L. Gruson. R., Cameron (1985). Metacognitive Assessment. The Growth of Reflection in Children. S. Yussen. London, Academic Press: 3-30.

Miles, M. and A. Huberman (1984). Qualitative Data Analysis. Beverly Hills, California, Sage Publications.

Mulcahy, R., R. Short., J. Andrews (1991). Enhancing Learning and Thinking. New York, Praeger.

Munro, J. (1993a). Strategy Training and Mathematics Learning Disabilities. Proceedings of the Sixteenth Annual Conference of the Mathematics Education Research Group of Australasia, Brisbane, Queensland, MERGA.

Nisbett, R. and T. Wilson (1977). "Telling More than we can Know: Verbal reports on mental processes." Psychological Review 84(3): 231-259.

Nuthall, G. and A. Alton-Lee (1995). "Assessing Classroom Learning: How students use their knowledge and experience to answer classroom achievement test questions in science and social studies." American Educational Research Journal 32(1): 185-223.

Pines, A., J. Novak. G., Posner. J., Van Kirks (1978). The Clinical Interview: A method for evaluating cognitive structure. Ithaca New York, Department of Education, Cornell University.

Randhawa, B. (1994). "Theory, Research, and Assessment of Mathematical Problem Solving." The Alberta Journal of Educational Research XL(2): 213-231.

Reid, J. (1990). "The Dirty Laundry of ESL Survey Research." TESOL Quarterly 24: 323-338.

Savage, L. (1994). Testing the Limits: Tool for Assessing Metacognitive Skills and the Zone of Proximal Development. West Virginia, ERIC Document ED 375 168: 1-8.

Schoenfeld, A. (1985). Mathematical Problem Solving. Orlando, Florida, Academic Press.

Scott, N. (1994). Profiles of some Non-Routine Problem Solving Episodes. Challenges in Mathematics Education: Constraints on Construction: Proceeedings of the Seventeeth Annual Conference of the Mathematics Education Research Group of Australasia, Lismore, Australia, MERGA.

Stacey, K. (1990). "Making Optimal use of Mathematical Knowledge." Australian Journal of Remedial Education 22: 6-10.

Usnick, V. and S. Brown (1992). "Assessing Elementary Students' Mathematical Thinking Through Interpersonal Process Recall." Focus on Learning Problems in Mathematics 14(4): 56-62.

Weinstein, C. and D. Meyer (1991). Implications of Cognitive Psychology for Testing: Contributions from work in Learning Strategies. Testing and Cognition. M. Wittrock and E. Baker. Englewood Cliffs, New Jersey, Prentice Hall: 40-61.

Wellman, H., Ed. (1985). The Child's Theory of Mind: The Development of Conscious Cognition. The Growth of Reflection in Children. San Diego, Academic Press.

Wilson, J. (2000) Assessing Metacognition. PhD Thesis, The University of Melbourne.

The **metacognitive action cards** included:

I thought about what I already know (Awareness)

I tried to remember if I had ever done a problem like this before (Awareness)

I thought about something I had done another time that had been helpful (Awareness)

I thought 'I know this sort of problem' (Awareness)

I thought 'I know what to do' (Awareness)

I thought 'Is this right?' (Evaluation)

I thought 'I cant do it.' (Evaluation)

I thought about how I was going (Evaluation)

I thought about whether what I was doing was working (Evaluation)

I checked my answer as I was working (Evaluation)

I made a plan to work it out (Regulation)

I thought about a different way to solve the problem (Regulation)

I thought about what I would do next (Regulation)

I changed the way I was working (Regulation)

The **cognitive action cards** for the logic and number tasks included:

I asked for help

I drew a diagram

I read the question again

I added

I subtracted

I multiplied

I divided

I counted

The **cognitive action cards** for the tangram task included:

I tried to see if a shape would fit

I moved a shape around

I turned a shape over

I tried a different shape